Early Journal Content on JSTOR, Free to Anyone in the World

This article is one of nearly 500,000 scholarly works digitized and made freely available to everyone in the world by JSTOR.

Known as the Early Journal Content, this set of works include research articles, news, letters, and other writings published in more than 200 of the oldest leading academic journals. The works date from the mid-seventeenth to the early twentieth centuries.

We encourage people to read and share the Early Journal Content openly and to tell others that this resource exists. People may post this content online or redistribute in any way for non-commercial purposes.

Read more about Early Journal Content at http://about.jstor.org/participate-jstor/individuals/early-journal-content.

JSTOR is a digital library of academic journals, books, and primary source objects. JSTOR helps people discover, use, and build upon a wide range of content through a powerful research and teaching platform, and preserves this content for future generations. JSTOR is part of ITHAKA, a not-for-profit organization that also includes Ithaka S+R and Portico. For more information about JSTOR, please contact support@jstor.org.

VI

ENGINEERING ASPECTS.

By JEROME C. HUNSAKER, Eng.D.

1. It is of especial significance that the American Philosophical Society devotes an afternoon to aëronautics and of especial significance to the Navy that the problems of aëronautics have been so clearly stated to you here today. For these problems are unfortunately not only perplexing but pressing, and engineering progress cannot wait for a satisfactory solution. Just now we are forced to adopt rather daring assumptions and to extrapolate to a truly alarming extent our experimental data.

2. I was sorry to arrive too late to hear Professor Webster's treatment of the dynamical aspects of the subject, but I shall have, of course, the opportunity for a more leisurely study of his paper when it appears in printed form.

3. Professor Durand's estimate of the economical size of aëroplanes is especially timely as we are building all sizes now in search of the most useful, and it is indeed encouraging to have Professor Durand as authority for making haste slowing in expanding the dimensions of the existing types. If I understand him correctly, the weight of the structure of aëroplane wings may be assumed to increase more rapidly than their carrying power so that there must be a limiting size for any given system of construction beyond which it is uneconomical to go. I believe this conclusion to be entirely true provided, as Professor Durand carefully states, the same system of construction be used for a family of similar structures. However, I would consider that it would not be good engineering to use the same material or even the same system of distributing material, for large and for small structures. For example, it is not economical to apply the materials and methods of construction used in small boats to large ships. Where we would use solid spruce beams for small wings, larger wings would have hollow spruce beams, and perhaps

still larger wings, beams of aluminum alloy or steel. In the great aëroplanes of the future, we may have an opportunity to use a lattice construction combining a great moment of inertia with a minimum of material. The smaller the structure the less favorably can we employ the material. In many cases to give sufficient security against local injury and deterioration we make parts several times stronger than would be indicated by a strength calculation alone. For example, no matter how small the aëroplane, we would use no less than a certain minimum rib thickness and cover with a fabric of sufficient weight and strength to stand exposure. Consequently, in the small aëroplanes, we build relatively heavier than necessary.

4. The exploration of the upper air has now become of pressing concern to those who expect to navigate in it and, in a general way, to designers of aircraft. Dr. Blair's soundings are most illuminating and it is especially gratifying to note the progress which our own Weather Bureau is making in this work. For the airship and balloon, especially, a knowledge of the pressure, temperature, and wind at different altitudes is of first importance and it is to be hoped that forecasts can be supplied the aëronant before his ascent, which will acquaint him with the probable conditions he will encounter aloft. Dr. Blair's data, I assume, show typical conditions or rather average conditions. It would be valuable if his explorations of the upper air could be extended to show in addition the possible and typical deviations from average values. The aviator is less concerned with the average velocity of the wind than with its internal structure; the frequency and intensity of its gusts and their nature.

5. The importance of a study of gusts is clearly brought out by Professor Wilson's analysis of the effect of lateral gusts on an aëroplane in flight. Professor Wilson has assumed gusts of given intensity and direction and computed the effect upon a typical aëroplane. There is abundant testimony of a qualitative nature as to the violence of these effects in practice. Aviators speak of "air holes" in explanation of uncontrolled diving and turning experienced. It is of course evident that there are no holes in the air, and Professor Wilson shows that gusts produce effects of the sort observed. Now it is possible in the design of aëroplanes to so arrange surfaces that the effect of particular kinds of gusts is minimized. What we need

to know now is what kinds of gusts are to be expected. For example, if sudden horizontal shifts in the direction of the wind are the usual state of affairs, we should not put a great preponderance of vertical fin surface on the tails of our aëroplanes. An excessive "weather-cock" propensity will make a machine head into the relative wind and if the wind direction shifts constantly it will be difficult to maintain a straight course. The "weather-cock" stability is of course provided to make steering easier.

6. Also Professor Wilson shows that a roller in the air is certain to bring disaster to an aëroplane. We have evidence of rotation in the eddy formed in the lee of a hill or other obstruction, but there is little information as to the extent and intensity of the disturbance. What aviators call "bad air" may be eddies in the wind.

7. I would appreciate the opportunity to outline in a general way some of the problems of lighter-than-air craft, airships and balloons, in order to make the symposium more complete.

8. In the design of airships we are confronted with indeterminate structural features, mysteries of the upper air, atmospheric electrical phenomena, and in addition to these difficulties we must work with fabrics and membranes of unfamiliar and indefinite physical properties.

9. The theory of hydrogen-filled balloons was developed in a very elaborate and complete form by the pioneers of the French Army Engineering Corps. Their theoretical considerations are of the greatest practical utility but depend upon an assumed stable condition of the atmosphere. Unfortunately a balloon and to a less degree a dirigible or airship is extremely sensitive to changes of equilibrium. For example, a balloon floating at its zone of equilibrium has exactly the weight of the air displaced. A wet cloud may condense a little water on its surface, the balloon will sink into regions of more dense air which will compress its volume and cause continued descent until ballast is released or the ground reached.

10. An airship is also handicapped by changes of weight in the air due to picking up loads of condensed water, snow, or sleet. The balloon fabric should be proofed in some manner to prevent such accumulations.

11. At the same time, though weight may not change, tempera-

ture variations cause expansion and contraction of gas and consequent changes in buoyancy. We may expect the air to grow at least 0.5° colder for each 100 meters rise, but this is rather an average than a normal condition.

12. Only at night is the gas at the same temperature as the air, for the sun's heat on the balloon keeps the gas inside 10 to 20 degrees warmer. A cloud which cuts off this radiation will cause a contraction of the gas enough to cause a descent. It is of great importance to check temperature changes in the gas. Airships have been given metallic flake paints, and light colors in an effort to reduce heating. The most effective means would appear to be a double wall with air space as in the Zeppelin type. Aluminum paint was found to reflect fourteen times as much radiant heat as unprotected rubber.

13. Rubberized fabric has been the envelope material for nearly all dirigibles except Zeppelins. Such fabric can be obtained in quantity and of uniform quality. Unfortunately the chemical action of light causes the rubber to deteriorate. Protective coatings of chrome yellow have been used with fair success. More recently carbon black has been found to protect the rubber better. But a dark envelope exaggerates the disturbances of equilibrium due to heating.

14. The hydrogen leakage through good rubberized fabric should be about 9 liters per square meter per day. Goldbeater's skin, which is animal intestine, tanned, shows a leakage of but a quarter of a liter. Such a membrane is immensely superior as a hydrogen container and does not oxidize. However, gold-beater's skin rots if wet, is difficult to work and to obtain in quantity. It is to be hoped that a hydrogen-tight material can be developed equal to goldbeater's skin but without these disadvantages.

15. The envelope of a dirigible is a nonconductor of electricity, but presumably picks up the electro-static potential of the air. Experiments with kites have shown a potential difference of 20,000 volts at 1,000 meters. It is likely that an airship takes up the potential of the air in less than a second and cannot reach the ground even after a rapid descent with any very considerable charge. The potential gradient may be 50 volts per meter and a dirigible of 20

meters height may have different charges above and below which may cause sparks and consequent explosion of the leaking hydrogen. There have been explosions for which no explanation is adequate. Should high metal parts such as valves have a wire to the car as a ground, or should we use a valve cord of non-conducting material?

16. The addition of radio on an airship for signaling introduces another complication. The radio uses the car as a counterpoise and has a trailing wire as antenna. It is possible that sparking between car and envelope may be induced when sending unless precautions are taken. The nature of the necessary precautions is at present not clearly understood.

17. The structural strength of the envelope of a nonrigid dirigible is not yet a definite engineering problem. As you know a torpedo-shaped elongated envelope inflated with hydrogen carries by means of a set of cables a car containing passengers and power plant. The buoyancy of the envelope is distributed from end to end of the envelope, but the weight is largely concentrated in the short car. Hence there are serious bending moments impressed on the envelope which is held stiff only by its pressure of inflation. The well-known theory of an elastic membrane can be used to compute the stress in the envelope at any point due to the inflation pressure. However, the stresses due to these bending moments must also be considered, and at a high velocity the suction of the stream line motion of the external air tends to augment the effective inflation pressure at points near the maximum cross section.

18. In addition to stresses due to inflation pressure, bending moments and external pressures and suctions, we have our problem confused from an engineer's point of view by having to deal with balloon fabric of indefinite elasticity and strength.

19. The strength of the fabric in warp and filler may be measured, but when we use a doubled fabric in which the threads cross at 45° the strength becomes more difficult to estimate. Furthermore, the envelope under load deforms and parts severely stressed may shirk their load. The exact calculation of the stress in an envelope is not attempted.

20. There is, however, a simple experimental method of studying the problem. A model of the envelope filled with water is

suspended below a model of the car by a suspension of cords. The ratio of densities of hydrogen and water in air is about 900 and it can be shown that if the scale of a model be $1/30$ and that if the model is made of the same material, the stresses at corresponding points are equal and the model as it deforms under load remains similar to the full size envelope as it would deform under corresponding loads.

21. Finally we have to consider the dynamical problem of driving the dirigible through the air at high speeds. As is well known to students of hydrodynamics, an elongated body tends to place itself broadside to the stream. Dirigibles of good form are essentially unstable and it is necessary to fit fins at the tail end. It is not practicable or necessary to fit very large horizontal fins since the center of gravity is usually below the center of buoyancy and hence affords a statical righting couple against pitching. This statical righting moment is supposed to overcome the tendency of the envelope to deviate from the trajectory. However, as speed is increased the upsetting moment increases as the square of the speed, while the statical righting moment of weight remains constant. Consequently, there is some critical speed at which the dirigible becomes unstable or even unmanageable.